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ABSTRACT

Presented are the teacher's guide and student manual for one of a series of self-instructional, computer-based learning modules for an introductory, undergraduate chemistry course. The student module for this unit on dilution problems includes objectives, prerequisites, pretest, discussion, and 10 problem sets. Included in the teacher's guide are implementation instructions, answers to problems, software, computing references, sample run, program listing in BASIC, and 10 unit tests. (BT)

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SOLUTIONS

UNIT 3. DILUTION PROBLEMS

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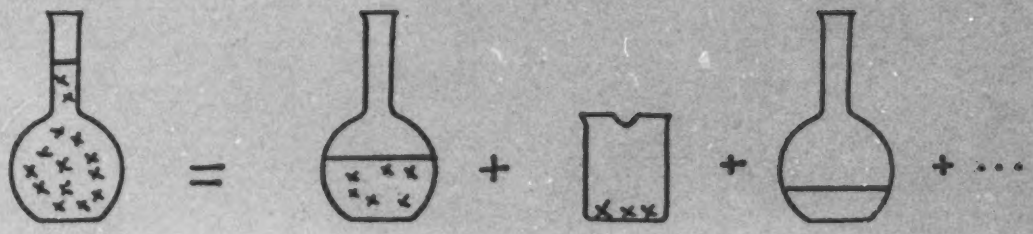
XAVIER UNIVERSITY

A COMPUTER-ENRICHED MODULE
FOR INTRODUCTORY CHEMISTRY

moles in the final solution = moles from the 1st source + moles from the 2nd source + ...



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OBJECTIVES

When you finish this unit you will be able to

1. work dilution problems using conversion factors.
2. prepare solutions of known concentrations from pure solute and/or other solutions.

PREREQUISITES

Before beginning this module you should be familiar with conversion factors and understand the definitions of mole, solute, solvent, solutions, and molar concentration.

PRE-TEST

1. The formula weight of sodium chloride is 58.44 g/mole. How many moles are there in 14.61 g of sodium chloride?
2. If 4.0 moles of sodium chloride are dissolved in enough water to produce 500.0 ml of solution, what is the molarity of the sodium chloride in the resultant solution?
3. The density of mercury (200.6 g/mole) is 13.6 g/ml. How many moles of mercury are there in 6.71 ml of mercury?

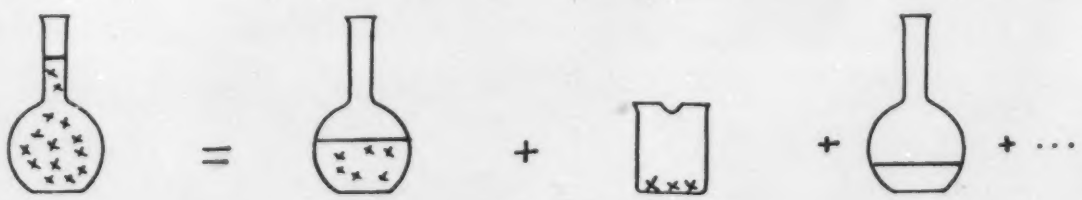
Answers to pre-test:

1. 0.2500 moles
2. 8.0 molar
3. 0.454 moles

INTRODUCTION

Dilution problem calculations are based on the simple rule that moles of solute are conserved, i.e., the number of moles of solute that are put into a container doesn't change.

$$\text{moles}\begin{pmatrix}\text{in the final}\\ \text{solution}\end{pmatrix} = \text{moles}\begin{pmatrix}\text{from the}\\ \text{1st source}\end{pmatrix} + \text{moles}\begin{pmatrix}\text{from the}\\ \text{2nd source}\end{pmatrix} + \cdots$$



The number of moles at any stage can be obtained by using conversion factors and the information given.

Example 1. How many moles of NaOH (40.0 g/mole) are there in 10.0 g of NaOH?

$$(10.0 \text{ g NaOH})\left(\frac{1 \text{ mole NaOH}}{40.0 \text{ g NaOH}}\right) = 0.250 \text{ moles NaOH}$$

Example 2. How many moles of NaOH are there in 200.0 ml of 3.0 molar NaOH solution?

$$(200.0 \text{ ml NaOH soln})\left(\frac{1 \text{ liter NaOH soln}}{1000 \text{ ml NaOH soln}}\right)\left(\frac{3.0 \text{ moles NaOH}}{\text{liter NaOH soln}}\right) = 0.60 \text{ moles NaOH}$$

The problem therefore reduces to expanding previous experiences with conversion factors to include dilution.

On important fact to remember is that volume of solution, unlike moles of solute, is not conserved. If one wished to cut in half the concentration of 25.00 ml of solution, one should add enough solvent (the added amount need not be measured) to make the final volume 50.0 ml.

Proceed to use the program DILUTE. It will give you three problems to work, and will detect any dimensional errors that you might make. Copy your answers, as directed, on the work sheet below. Once you have worked all three problems you can be confident that you understand the fundamentals of dilution.

Results of the Program DILUTE

Problem #1

moles NaOH =

molarity of NaOH solution =

Problem #2

moles NaOH =

volume NaOH solution =

Problem #3

(1st source) moles NaOH =

(2nd source) moles NaOH =

(total) moles NaOH =

(final) molarity of NaOH solution =

DISCUSSION

The simple rule for dilution, that the total number of moles of solute is unchanged, can be applied even when initial data is given in other than weight-molecular weight or molarity-volume terms.

Example 3. How many moles of Br_2 (160 g/mole) are there in 3.0 ml of pure Br_2? (the density of Br_2 is 3.1 g/ml)

$$(3.0 \text{ ml } Br_2)\left(\frac{3.1 \text{ g } Br_2}{\text{ml } Br_2}\right)\left(\frac{1 \text{ mole } Br_2}{160 \text{ g } Br_2}\right) = 0.058 \text{ moles } Br_2$$

Example 4. How many moles of sulfuric acid (98.0 g/mole) are there in 12.0 ml of a solution which is 75% (by weight) H_2SO_4 and which has a density of 1.67 g/ml?

$$(12.0 \text{ ml } H_2SO_4 \text{ soln})\left(\frac{1.67 \text{ g } H_2SO_4}{\text{ml } H_2SO_4 \text{ soln}}\right)\left(\frac{0.75 \text{ g } H_2SO_4}{\text{g } H_2SO_4 \text{ soln}}\right)\left(\frac{1 \text{ mole } H_2SO_4}{98.0 \text{ g } H_2SO_4}\right) =$$

$$= 0.15 \text{ moles } H_2SO_4$$

Problem 5. A 10.0 g sample of benzene (78.1 g/mole) which occupies 11.4 ml and a 50.0 g sample of ethyl alcohol (46.1 g/mole) which occupies 63.7 ml are dissolved in one another. The resultant solution occupies 73.8 ml. What is the molarity of benzene in this solution?

Problem 6. A 10.0 liter polyethylene bottle containing an NaOH solution of unknown concentration has been found. When 50.0 ml of this solution was mixed with 25.0 ml of 0.1000 molar NaOH and enough water to make 100.0 ml of solution, this final solution was 0.2000 molar in NaOH. What was the molarity of the NaOH solution in the bottle?

Problem 7. The density of acetone is 1.08 g/ml and that of water 1.00 g/ml. When 11.0 ml of acetone (58.1 g/mole) is dissolved in 91.0 ml of water (18.0 g/mole) the resultant solution occupies 100.0 ml. What is the molarity of acetone in the final solution?

Problem 8. When 0.0213 g of NaOH (40.0 g/mole) and 0.0132 g of $Ca(OH)_2$ (74.10 g/mole) are placed in a beaker, and enough water added to give 500 ml of solution, what is the molar concentration of hydroxide ion? (Remember that each mole of $Ca(OH)_2$ gives <u>two</u> moles of OH^-.)

Problem 9. What volume of 0.1000 molar NaOH must be added to 250.0 ml of 0.500 molar NaOH in order to prepare 1.00 liter of 0.200 molar NaOH? (Sufficient water will be added to make the final volume 1.00 l.)

Problem 10. What weight of solid NaOH (40.0 g/mole) must be added to 250.0 ml of 0.500 molar NaOH in order to prepare 1.00 l of 0.200 molar NaOH?

Problem Set 1

1. 11.0 ml of a 2.870 M solution of $NaClO_3$ is diluted to 50 ml. What is the molarity of the new solution?

2. To what final volume must one dilute 196 ml of a solution containing 10.3 g KNO_3 to make the final solution 0.386 M?

3. A 75.8 ml sample of concentrated $MnCl_2$ solution is diluted until the final volume is 104.0 ml. The density of the concentrated solution is 1.1 g/ml and it is 20.4% pure $MnCl_2$. What is the molarity of the final solution?

4. What will be the molarity of a solution made up by mixing 29 ml of a 1.018 M solution of $Al_2(SO_4)_3$ with 1 ml of a 0.46 M solution of $Al_2(SO_4)_3$? Volumes can be considered additive.

5. How many ml of 3.430 M $CuSO_4 \cdot 5H_2O$ is required in the preparation of 95.7 ml of 0.182 M $CuSO_4 \cdot 5H_2O$?

6. How many ml of 61.1% KIO_3 solution should be used to prepare 49 ml of 0.739 M KIO_3? The density of the concentrated solution is 1.161 g/ml.

Problem Set 2

1. 24.5 ml of a 3.235 M solution of $MgSO_4$ is diluted to 275 ml. What is the molarity of the new solution?

2. What will be the molarity of the $AgNO_3$ solution if 18.8 ml of water is added to 39.3 ml of 0.485 M $AgNO_3$? Volumes can be considered additive.

3. A 5.6 ml sample of concentrated $CaBr_2$ solution is diluted until the final volume is 26.7 ml. The density of the concentrated solution is 1.2 g/ml and it is 74.3% pure $CaBr_2$. What is the molarity of the final solution?

4. How many ml of 54.4% $MnCl_2$ solution should be used to prepare 84 ml of 1.497 M $MnCl_2$? The density of the concentrated solution is 1.154 g/ml.

5. What will be the molarity of a solution made up by mixing 79 ml of a 0.253 M solution of $Cd(NO_3)_2$ with 4 ml of a 0.78 M solution of $Cd(NO_3)_2$? Volumes can be considered additive.

6. How many ml of 1.580 M KNO_3 is required in the preparation of 77.3 ml of 0.841 M KNO_3?

Problem Set 3

1. What will be the molarity of a solution made up by mixing 15 ml of a 0.484 M solution of $MgSO_4$ with 40 ml of a 0.93 M solution of $MgSO_4$? Volumes can be considered additive.

2. How many ml of 3.870 M $NaClO_3$ is required in the preparation of 33.5 ml of 0.394 M $NaClO_3$?

3. How many ml of 15.0% $Ni(NO_3)_2$ solution should be used to prepare 120 ml of 0.620 M $Ni(NO_3)_2$? The density of the concentrated solution is 1.115 g/ml.

4. To what final volume should one dilute 117 ml of a solution containing 4.8 g of $Cd(NO_3)_2$ to make the final solution 0.073 M?

5. 47.5 ml of a 2.185 M solution of $FeCl_3$ is diluted to 275 ml. What is the molarity of the new solution?

6. A 94.1 ml sample of concentrated $Cd(NO_3)_2$ solution is diluted until the final volume is 200.5 ml. The density of the concentrated solution is 1.1 g/ml and it is 7.6% pure $Cd(NO_3)_2$. What is the molarity of the final solution?

Problem Set 4

1. To what final volume must one dilute 391 ml of a solution containing 8.9 g of $FeCl_3$ in order to make the final solution 0.096 M?

2. A 38.6 ml sample of concentrated $BaCl_2$ solution is diluted until the final volume is 102.1 ml. The density of the concentrated solution is 1.2 g/ml and it is 61.2% pure $BaCl_2$. What is the molarity of the final solution?

3. Enough water is added to 39.5 ml of 0.396 M $Cd(NO_3)_2$ to make the final volume 103.8 ml. What is the molarity of $Cd(NO_3)_2$ in the final solution?

4. 28.9 ml of a 4.060 M solution of $BaCl_2$ is diluted to 891 ml. What is the molarity of the new solution?

5. How many ml of 84.0% $(NH_4)_3PO_4$ solution should be used to prepare 169 ml of 1.883 M $(NH_4)_3PO_4$? The density of the concentrated solution is 1.184 g/ml.

6. What will be the molarity of a solution made up by mixing 1 ml of a 1.570 M solution of $MgSO_4$ with 15 ml of a 3.93 M solution of $MgSO_4$? Volumes can be considered additive.

Problem Set 5

1. 15.6 ml of a 2.370 M solution of $NaClO_3$ is diluted to 366 ml. What is the molarity of the new solution?

2. What will be the molarity of a solution made up by mixing 53 ml of a 0.970 M solution of KIO_3 with 26 ml of a 0.85 M solution of KIO_3?

3. How much water must be added to 482 ml of a solution containing 5.4 g of $CrCl_3$ to make the final solution 0.054 M? Volumes can be considered additive.

4. How many ml of 84.1% KNO_3 solution should be used to prepare 116 ml of 3.571 M KNO_3? The density of the concentrated solution is 1.184 g/ml.

5. When 45.9 ml of 0.655 M Na_2CO_3 is diluted to 68.6 ml, what is the molarity of Na_2CO_3 in the final solution?

6. A 51.0 ml sample of concentrated $MnCl_2$ solution is diluted until the final volume is 151.6 ml. The density of the concentrated solution is 1.1 g/ml and it is 12.4% pure $MnCl_2$. What is the molarity of the final solution?

Problem Set 6

1. To what final volume must one dilute 494 ml of a solution containing 5.7 g of $Cd(NO_3)_2$ to make the final solution 0.041 M?

2. 21.7 ml of a 3.270 M solution of $NaClO_3$ is diluted to 899 ml. What is the molarity of the new solution?

3. How many ml of 4.31[illegible] M $FeCl_3$ is required in the preparation of 38.0 ml of 0.277 M $FeCl_3$?

4. How many ml of 32.0% $(NH_4)_3PO_4$ solution should be used to prepare 112 ml of 1.195 M $(NH_4)_3PO_4$? The density of the concentrated solution is 1.132 g/ml.

5. What will be the molarity of a solution made by mixing 30 ml of a 0.667 M solution of KIO_3 with 22 ml of 2.15 M KIO_3? The final volume is 52 ml.

6. What will be the molarity of the $Al_2(SO_4)_3$ solution if 80.0 ml of water is added to 7.7 ml of 0.193 M $Al_2(SO_4)_3$?

Problem Set 7

1. How many ml of 3.520 M $FeCl_3$ is required in the preparation of 62.7 ml of 0.217 M $FeCl_3$?

2. A 13.7 ml sample of concentrated $K_2Cr_2O_7$ solution is diluted until the final volume is 50.0 ml. The density of the concentrated solution is 1.2 g/ml and it is 63.8% pure $K_2Cr_2O_7$. What is the molarity of the final solution?

3. 16.7 ml of a 2.620 M solution of $MnCl_2$ is diluted to 699 ml. What is the molarity of the new solution?

4. What will be the molarity of a $NaClO_3$ solution if 14.4 ml of a 0.754 M $NaClO_3$ solution is diluted to 104.3 ml?

5. How many ml of 53.9% $KMnO_4$ solution should be used to prepare 177 ml of 1.408 M $KMnO_4$? The density of the concentrated solution is 1.154 g/ml.

6. What will be the molarity of a solution made up by mixing 79 ml of a 2.263 M solution of $MnCl_2$ with 15 ml of a 1.42 M solution of $MnCl_2$? Volumes can be considered additive.

Problem Set 8

1. How many ml of 1.330 M $BaCl_2$ is required in the preparation of 41.4 ml of 0.212 M $BaCl_2$?

2. 38.8 ml of a 1.405 M solution of KNO_3 is diluted to 934 ml. What is the molarity of the new solution?

3. How many ml of 98.5% $AgNO_3$ solution should be used to prepare 131 ml of 1.504 M $AgNO_3$? The density of the concentrated solution is 1.198 g/ml.

4. To what final volume must 79 ml of a solution containing 4.3 g of $BaCl_2$ be diluted in order to make the final solution 0.120 M $BaCl_2$?

5. What will be the molarity of a $FeCl_3$ solution if 28.8 ml of 0.657 M $FeCl_3$ is diluted to 130.7 ml?

6. A 9.4 ml sample of concentrated $Al_2(SO_4)_3$ solution is diluted until the final volume is 111.8 ml. The density of the concentrated solution is 1.1 g/ml and it is 35.3% pure $Al_2(SO_4)_3$. What is the molarity of the final solution?

Problem Set 9

1. What is the molarity of a solution made by mixing 14 ml of 1.027 M $Ni(NO_3)_2$ with 42 ml of 4.85 M $Ni(NO_3)_2$? The final volume is 56 ml.

2. How many ml of 75.6% $Cd(NO_3)_2$ solution should be used to prepare 112 ml of 1.654 M $Cd(NO_3)_2$? The density of the concentrated solution is 1.176 g/ml.

3. 33.7 ml of a 2.770 M solution of $NaClO_3$ is diluted to 979 ml. What is the molarity of the new solution?

4. A 88.7 ml sample of concentrated $Cd(NO_3)_2$ solution is diluted until the final volume is 180.8 ml. The density of the concentrated solution is 1.1 g/ml and it is 43.6% pure $Cd(NO_3)_2$. What is the molarity of the final solution?

5. A 53.8 ml sample of 0.854 M $NaClO_3$ is diluted to 60.6 ml. What is the molarity of the final $NaClO_3$ solution?

6. How many ml of 3.770 M $K_2Cr_2O_7$ is required in the preparation of 65.3 ml of 0.538 M $K_2Cr_2O_7$?

Problem Set 10

1. 37.5 ml of a 4.705 M solution of KNO_3 is diluted to 275 ml. What is the molarity of the new solution?

2. How much water must be added to 287 ml of a solution containing 1.5 g of $BaCl_2$ to make the final solution 0.016 M? Volumes can be considered additive.

3. How many ml of 87.9% $KMnO_4$ solution should be used to prepare 169 ml of 3.692 M $KMnO_4$? The density of the concentrated solution is 1.188 g/ml.

4. What will be the molarity of the $CrCl_3$ solution if 17.1 ml of 0.529 M $CrCl_3$ is diluted to 60.0 ml?

5. What will be the molarity of a solution made up by mixing 22 ml of a 2.305 M solution of $(NH_4)_3PO_4$ with 4 ml of a 2.70 M solution of $(NH_4)_3PO_4$? Volumes can be considered additive.

6. How many ml of 3.970 M Na_2CO_3 is required in the preparation of 67.4 ml of 0.255 M Na_2CO_3?

The CM Project

The Computer-enriched Module (CM) project is a collaborative effort by 19 faculty members in the disciplines of chemistry, mathematics and physics, to produce self-instructional computer-based materials at the introductory college level in those disciplines. Each module is designed to be usable in an academic environment with minimal computational facilities, and by students and faculty who are not programming experts. It may be used as an adjunct to standard textual materials, or in many cases, as a replacement for them. The primary aim of each module is to use the computer in such a way that students may take a more active role in the development and discovery of concepts and phenomena.

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TEACHER'S GUIDE TO

A MODULE ON SOLUTIONS

UNIT 3. DILUTION PROBLEMS

RICHARD T. O'NEILL

XAVIER UNIVERSITY

a computer-enriched module

for introductory chemistry

featuring the program

DILUTE

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TEACHER'S GUIDE TO UNIT ON DILUTION PROBLEMS OF THE SOLUTIONS MODULE

EDUCATIONAL OBJECTIVES

This study unit is designed to reinforce the conversion factor method and dimensional analysis introduced earlier. Specifically it gives a new method for finding moles, fulfilling the promises of the stoichiometry module.

IMPLEMENTATION

This is a very short (about one period) unit which is in some sense a review. It can provide the student with a "breather" between Unit 2 (molarity, molality, and concentration conversions) and Unit 4 (solution stoichiometry) which introduce more matter and require more time.

In the tutorial computer program, each student has his own data, and the numbers are such that the arithmetic can usually be done mentally. Each problem is worked step by step, and the student cannot proceed to a new step with a misconception or a wrong value. Diagnostics are presented for likely errors but, knowing students' inventiveness, no claim is made that every wrong answer can be identified with a specific student misconception. When the misconception can be identified, the student is told the consequences of his choice in terms of the units involved -- e.g. if he has divided molarity by volume, he is shown that his units are moles/(liter)^2, not moles. If the student's answer is correct to within 5%, the exact answer and units are printed out, he is told exactly what he did to get this, and required to copy the analysis onto the worksheet in his student guide. Five errors on a single question will end the program with a message to restudy his guide before trying the program again.

It should perhaps be pointed out to the student that NaOH is not really a primary standard -- he cannot weigh out 40.0 g from the bottle on the shelf and have 1.00 moles. Nonetheless the compound was chosen as a representative chemical because of its importance in acid-base chemistry, and because its formula weight is a "nice" number.

Very few sample problems are worked in the student's guide since the three fundamental types of problems are covered in the tutorial computer program. It is expected that the instructor will assign the six basic problems (5 to 10) which are worked in the teacher's guide; the instructor may also wish to assign one of the ten problem sets for which the answers are provided in the teacher's guide.

Problems 5-10

The first two problems are similar to those given in the computer program. The others are simple extensions. It is recommended that the student refer back to the picture at the beginning of his guide if he doesn't know how to begin a problem.

Often the hardest part of a problem is choosing which data is appropriate to use. Problems 5 and 7 give superfluous data.

In analytical chemistry (especially titrations) four significant figure concentrations are often required. Since it requires much more effort to prepare such solutions, they should not be used frivolously.

ANSWERS TO PROBLEMS

Pre-test

a. $(14.61 \text{ g NaCl})\left(\frac{1 \text{ mole NaCl}}{58.44 \text{ g NaCl}}\right) = 0.2500 \text{ moles NaCl}$ (note significant figures)

b. $\left(\frac{4.0 \text{ moles NaCl}}{500.0 \text{ ml NaCl soln}}\right)\left(\frac{1000 \text{ ml NaCl soln}}{1 \text{ liter NaCl soln}}\right) = \frac{8.0 \text{ moles NaCl}}{\text{liter NaCl soln}} = 8.0 \text{ molar}$

c. $(6.71 \text{ ml Hg})\left(\frac{13.6 \text{ g Hg}}{\text{ml Hg}}\right)\left(\frac{1 \text{ mole Hg}}{200.6 \text{ g Hg}}\right) = 0.454 \text{ moles Hg}$

Problems

5. This is the same as the first problem in DILUTE with a different solvent and solute.

$$\text{moles benzene} = (10.0 \text{ g benzene})\left(\frac{1 \text{ mole benzene}}{78.1 \text{ g benzene}}\right)$$

$$\text{molarity benzene} = \left(\frac{\text{moles benzene}}{73.8 \text{ ml soln}}\right)\left(\frac{1000 \text{ ml soln}}{1 \text{ liter soln}}\right)$$

$$= \left(\frac{10.0}{78.1} \text{ moles benzene}\right)\left(\frac{1000}{73.8 \text{ liters soln}}\right)$$

$$= 1.75 \frac{\text{moles benzene}}{\text{liter soln}} = 1.75 \text{ molar benzene}$$

Note that the problem gave you more information than you needed. You <u>always</u> have more information than you need (at least you do if you have access to a chemical handbook) and it is often the most difficult part of a problem simply to decide what information should be used.

6. This question is really the same as the third problem in DILUTE, except that the final molarity is given, and the molarity of the

first source must be calculated.

moles NaOH (final) = moles NaOH (unknown soln) + moles NaOH (0.1 molar soln)

$$= \left(\frac{0.200 \text{ moles NaOH}}{1 \text{ liter soln}}\ 100 \text{ ml soln}\right)\left(\frac{1 \text{ liter soln}}{1000 \text{ ml soln}}\right)$$

$$= 0.0200 \text{ moles NaOH}$$

$$\text{moles NaOH (0.1 M source)} = \left(\frac{0.100 \text{ moles NaOH}}{1 \text{ liter soln}}\ 25 \text{ ml soln}\right)\left(\frac{1 \text{ liter soln}}{1000 \text{ ml soln}}\right)$$

$$= 0.0025 \text{ moles NaOH}$$

$$\text{moles NaOH (unknown solution)} = (0.0200 - 0.0025) \text{ moles NaOH}$$

$$= 0.0175 \text{ moles NaOH}$$

$$\text{molarity NaOH (unknown solution)} = \left(\frac{0.0175 \text{ moles NaOH}}{50 \text{ ml soln}}\right)\left(\frac{1000 \text{ ml soln}}{1 \text{ liter soln}}\right)$$

$$= 0.350 \frac{\text{moles NaOH}}{\text{liter soln}}$$

$$= 0.350 \text{ molar NaOH solution}$$

7. This question is similar to the first problem in DILUTE, except that the number of moles of solute is found from density-volume data for the pure solute, as in Example 3.

$$\text{moles acetone} = (11.0 \text{ ml acetone})\left(\frac{1.08 \text{ g acetone}}{\text{ml acetone}}\right)\left(\frac{1 \text{ mole acetone}}{58.1 \text{ g acetone}}\right)$$

$$= 0.204 \text{ moles acetone}$$

$$\text{molarity acetone} = \left(\frac{0.204 \text{ moles acetone}}{100 \text{ ml soln}}\right)\left(\frac{1000 \text{ ml soln}}{1 \text{ liter soln}}\right)$$

$$= 2.04 \frac{\text{moles acetone}}{\text{liter soln}}$$

$$= 2.04 \text{ molar acetone}$$

8. $(\text{moles } OH^-) = (\text{moles NaOH}) + 2(\text{moles } Ca(OH)_2)$

$$\text{moles NaOH} = (0.0213 \text{ g NaOH})\left(\frac{1 \text{ mole NaOH}}{40.0 \text{ g NaOH}}\right) = 5.32 \times 10^{-4} \text{ moles NaOH}$$

$$\text{moles } Ca(OH)_2 = (0.0132 \text{ g } Ca(OH)_2)\left(\frac{1 \text{ mole } Ca(OH)_2}{74.1 \text{ g } Ca(OH)_2}\right) = 1.78 \times 10^{-4} \text{ moles } Ca(OH)_2$$

moles OH^- = $5.32 \times 10^{-4} + 2(1.78 \times 10^{-4}) = 7.88 \times 10^{-4}$ moles OH^-

$$\text{molarity } OH^- = \left(\frac{7.88 \times 10^{-4} \text{ moles } OH^-}{500 \text{ ml soln}}\right)\left(\frac{1000 \text{ ml soln}}{1 \text{ liter soln}}\right)$$

$$= 1.58 \times 10^{-3} \frac{\text{moles } OH^-}{\text{liter soln}}$$

9. moles (final) = moles (1st source) + moles (2nd source)

$$\text{moles (final)} = \left(\frac{0.200 \text{ moles NaOH}}{1 \text{ liter soln}}\right)(1 \text{ liter soln}) = 0.200 \text{ moles NaOH}$$

$$\text{moles (1st source)} = \left(\frac{0.500 \text{ moles NaOH}}{1 \text{ liter soln}}\ 250 \text{ ml soln}\right)\left(\frac{1 \text{ liter soln}}{1000 \text{ ml soln}}\right)$$

$$= 0.125 \text{ moles NaOH}$$

moles (2nd source) = moles(final) - moles (1st source)
= (0.200 - 0.125) moles NaOH

$$\text{volume soln (2nd source)} = ((0.200 - 0.125) \text{ moles NaOH}) \cdot \left(\frac{1 \text{ liter soln}}{0.1000 \text{ moles NaOH}}\right)\left(\frac{1000 \text{ ml soln}}{1 \text{ liter soln}}\right)$$

= 750 ml soln = 0.75 l soln

Note that significant figures were lost in this process. The precise (four significant figure) concentration was divided into the number of moles of NaOH needed (two significant figures) giving a two significant figure volume. It's a pity that 0.10 molar naOH wasn't available Add 250 ml of 0.5 molar solution to 750 ml of 0.1000 molar solution, add water to get to 1.00 liter.

10. This is similar to the previous problem, except that the second source is pure solid NaOH. (0.200 - 0.125) moles NaOH = 0.075 moles NaOH are still needed.

$$\text{grams NaOH} = (0.075 \text{ moles NaOH})\left(\frac{40.0 \text{ g NaOH}}{\text{mole NaOH}}\right) = 3.0 \text{ g NaOH}$$

Weigh out 3.0 g NaOH, add to the 250 ml of 0.5 molar NaOH, and add enough water with stirring to make 1.00 liters of final solution. This way the assistant doesn't have to use any of the 0.1000 molar NaOH solution, which is rather hard to come by.

ANSWERS TO PROBLEM SETS

	SET 1		SET 2		SET 3		SET 4
1.	6.31E-01	1.	2.88E-01	1.	8.12E-01	1.	5.74E+02
2.	2.64E+02 ML	2.	3.28E-01	2.	3.41E+00	2.	1.29E+00
3.	1.32E+00	3.	9.15E-01	3.	8.11E+01	3.	1.51E-01
4.	1.00E+00	4.	2.51E+01	4.	2.78E+02	4.	1.32E-01
5.	5.08E+00	5.	2.78E-01	5.	3.77E-01	5.	5.06E+01
6.	1.09E+01	6.	4.11E+01	6.	1.67E-01	6.	3.79E+00

	SET 5		SET 6		SET 7		SET 8
1.	1.01E-01	1.	5.92E+02	1.	3.86E+00	1.	6.60E+00
2.	9.32E-01	2.	7.89E-02	2.	6.91E-01	2.	5.84E-02
3.	1.54E+02 ML	3.	2.44E+00	3.	6.26E-02	3.	2.84E+01
4.	4.21E+01	4.	5.83E+01	4.	9.50E-02	4.	1.59E+02
5.	4.38E-01	5.	1.30E+00	5.	6.34E+01	5.	1.45E-01
6.	3.69E-01	6.	1.69E-02	6.	2.13E+00	6.	9.85E-02

	SET 9		SET 10
1.	3.89E+00	1.	6.42E-01
2.	4.93E+01	2.	1.71E+02 ML
3.	9.53E-02	3.	9.46E+01
4.	9.03E+00	4.	1.51E-01
5.	7.58E-01	5.	2.37E+00
6.	9.32E+00	6.	4.33E+00

SOFTWARE

The BASIC program was constructed to be as machine-independent as possible. The only portions which may be system dependent are those which deal with random numbers (lines 200, 210) and computed GOTO's (lines 2060, 2120, 3060, 3120) and these can be changed easily.

The sample output which is attached could not have been obtained by a student, since he would have been cut off after making five errors on a single question. The cut off feature was disabled for this run in order to show all the diagnostic features.

The connect time for a single run of the program, assuming a 10 cps teletype, varies of course depending on the "thinking time" of the student. The minimum time, including writing down the analysis in the student's guide, is 5 minutes. There is no maximum time since a student can refuse to enter any data, but the five mistake cut off feature should prevent excessively long connect times. A typical student should take 15-20 minutes.

Computing References

The student who is interested in programming may be directed to "BASIC and Chemistry" by L. Soltzberg et. al., Chapter 9, and "Introduction to Computer Programming for Chemists -- BASIC Version" by C. Wilkins et. al., Chapter 5. These chapters deal principally with concentrations, with only one problem (9.1) in the first reference dealing specifically with dilution.

```
          DILUTE   Sample Run
  IN THIS TUTORIAL ON DILUTION, ANSWER THE QUESTIONS WITH
NUMBERS -- E.G  2.0 AND NOT 6/3 OR 1.33*1.5.

PRESS THE 'RETURN' OR 'NEW LINE' KEY AFTER TYPING THE NUMBER.

***** QUESTION #1

YOU WISH TO FIND THE MOLARITY OF NAOH IN A SOLUTION MADE BY
ADDING TO  10  G  OF NAOH (40.0 G /MOLE) ENOUGH WATER
TO MAKE  500  ML OF SOLUTION.

HOW MANY MOLES OF NAOH ARE THERE ? 4
(40.0 G /MOLE)/( 10 G )  HAS UNITS  '1/MOLE'

HOW MANY MOLES OF NAOH ARE THERE ? 20
YOU SEEM TO BE USING VOLUME. THERE ARE NO 'ML' OR 'LITERS' IN 'MOLES'.

HOW MANY MOLES OF NAOH ARE THERE ? .02
YOU SEEM TO BE USING VOLUME. THERE ARE NO 'ML' OR 'LITERS' IN 'MOLES'.

HOW MANY MOLES OF NAOH ARE THERE ? 80
  THIS ANSWER IS NOT WITHIN 5% OF THE CORRECT ANSWER, BUT
YOU MAY BE DOING THE PROBLEM CORRECTLY, AND MERELY MAKING
AN ARITHMETIC ERROR. CHECK YOUR CALCULATION WITH PENCIL
AND PAPER.

HOW MANY MOLES OF NAOH ARE THERE ? .251
RIGHT!!  THE EXACT ANSWER IS  .25  MOLES OF NAOH.
WRITE DOWN IN YOUR STUDENT GUIDE WHAT YOU DID --

E.G   ( 10  G NAOH)(1 MOLE NAOH)
      -------------------------
                (40.0 G NAOH)

WHAT IS THE MOLARITY OF THE NAOH IN THE SOLUTION? 2
( .5  LITERS) / ( .25  MOLES) HAS UNITS 'LITERS/MOLE'

WHAT IS THE MOLARITY OF THE NAOH IN THE SOLUTION? 500
  THIS ANSWER IS NOT WITHIN 5% OF THE CORRECT ANSWER, BUT
YOU MAY BE DOING THE PROBLEM CORRECTLY, AND MERELY MAKING
AN ARITHMETIC ERROR. CHECK YOUR CALCULATION WITH PENCIL
AND PAPER.

WHAT IS THE MOLARITY OF THE NAOH IN THE SOLUTION? .499
RIGHT! THE EXACT ANSWER IS  .5  MOLES NAOH/LITER NAOH SOLN.
WRITE DOWN IN YOUR STUDENT GUIDE WHAT YOU DID --

E.G   ( .25  MOLES NAOH)    (1000 ML NAOH SOLN)
      ---------------------------------------
      ( 500  ML NAOH SOLN) (1 LITER NAOH SOLN)
```

***** QUESTION #2

YOU WISH TO CALCULATE TO WHAT FINAL VOLUME (IN LITERS)
MUST 300 ML OF A .4 MOLAR SOLUTION OF NAOH BE
DILUTED IN ORDER TO PREPARE A .1 MOLAR NAOH SOLUTION.

HOW MANY MOLES OF NAOH ARE THERE ? 120
(300 ML)(.4 MOLES/LITER) HAS UNITS OF 'ML MOLES/LITER'.

HOW MANY MOLES OF NAOH ARE THERE ? .75
(.3 LITERS/(.4 MOLES/LITER) HAS UNITS OF
'LITERS SQUARED/MOLE'.

HOW MANY MOLES OF NAOH ARE THERE ? .03
UNITS ARE OKAY, BUT YOU ARE USING THE MOLARITY OF ONE SOLUTION,
AND THE VOLUME OF ANOTHER.

HOW MANY MOLES OF NAOH ARE THERE ? 1.33
(.4 MOLES/LITER)/(.3 LITERS) HAS UNITS OF
'MOLES/LITER SQUARED'.

HOW MANY MOLES OF NAOH ARE THERE ? .12
RIGHT!! THE EXACT ANSWER IS .12 MOLES OF NAOH.
WRITE DOWN IN YOUR STUDENT GUIDE WHAT YOU DID --

E.G (.4 MOLES NAOH)(300 ML NAOH SOLN) (1 LITER NAOH SOLN)

(1 LITER NAOH SOLN) (1000 ML NAOH SOLN)

WHAT IS THE FINAL VOLUME (IN LITERS) TO WHICH THIS .12
MOLES OF NAOH MUST BE DILUTED SO THAT .1
MOLES NAOH / LITER NAOH SOLUTION WILL BE THE
FINAL CONCENTRATION? .012
(.1 MOLES /LITER)(.12 MOLES) HAS UNITS 'MOLES SQUARED/LITER'

WHAT IS THE FINAL VOLUME (IN LITERS) TO WHICH THIS .12
MOLES OF NAOH MUST BE DILUTED SO THAT .1
MOLES NAOH / LITER NAOH SOLUTION WILL BE THE
FINAL CONCENTRATION? .83
(.1 MOLES/LITER)/(.12 MOLES) HAS UNITS '1/LITERS'

WHAT IS THE FINAL VOLUME (IN LITERS) TO WHICH THIS .12
MOLES OF NAOH MUST BE DILUTED SO THAT .1
MOLES NAOH / LITER NAOH SOLUTION WILL BE THE
FINAL CONCENTRATION? 1200
YOU WERE ASKED FOR LITERS, NOT ML

WHAT IS THE FINAL VOLUME (IN LITERS) TO WHICH THIS .12
MOLES OF NAOH MUST BE DILUTED SO THAT .1
MOLES NAOH / LITER NAOH SOLUTION WILL BE THE
FINAL CONCENTRATION? 1.2
RIGHT! THE EXACT ANSWER IS 1.2 LITERS OF NAOH SOLUTION.
WRITE DOWN IN YOUR STUDENT GUIDE WHAT YOU DID --

E.G (.12 MOLES NAOH) (1 LITER NAOH SOLN)

(.1 MOLES NAOH)

***** QUESTION #3

A 500 ML SAMPLE OF .2 MOLAR NAOH SOLUTION
IS MIXED WITH A 400 ML SAMPLE OF .3 MOLAR NAOH
SOLUTION. ENOUGH WATER IS THEN ADDED TO GIVE 1000 ML
OF SOLUTION. CALCULATE THE MOLARITY OF THE FINAL SOLUTION.

HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE .2 MOLAR SOLN? .15
UNITS ARE OKAY, BUT YOU ARE USING THE MOLARITY OF ONE SOLUTION,
AND THE VOLUME OF ANOTHER.

HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE .2 MOLAR SOLN? .08
UNITS ARE OKAY, BUT YOU ARE USING THE MOLARITY OF ONE SOLUTION,
AND THE VOLUME OF ANOTHER.

HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE .2 MOLAR SOLN? .2
UNITS ARE OKAY, BUT YOU ARE USING THE MOLARITY OF ONE SOLUTION,
AND THE VOLUME OF ANOTHER.

HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE .2 MOLAR SOLN? 100
(500 ML)(.2 MOLES/LITER) HAS UNITS OF 'ML MOLES/LITER'.

HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE .2 MOLAR SOLN? .4
(.2 MOLES/LITER)/(.5 LITERS) HAS UNITS OF
'MOLES/LITER SQUARED'.

HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE .2 MOLAR SOLN? 2.5
(.5 LITERS/(.2 MOLES/LITER) HAS UNITS OF
'LITERS SQUARED/MOLE'.

HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE .2 MOLAR SOLN? .1
RIGHT!! THE EXACT ANSWER IS .1 MOLES OF NAOH.
WRITE DOWN IN YOUR STUDENT GUIDE WHAT YOU DID --

E.G (.2 MOLES NAOH)(500 ML NAOH SOLN) (1 LITER NAOH SOLN)

(LITER NAOH SOLN) (1000 ML NAOH SOLN)

HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE .3 MOLAR SOLN? 120
(400 ML)(.3 MOLES/LITER) HAS UNITS OF 'ML MOLES/LITER'.

HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE .3 MOLAR SOLN? 1.3
(.4 LITERS/(.3 MOLES/LITER) HAS UNITS OF
'LITERS SQUARED/MOLE'.

HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE .3 MOLAR SOLN?
.75
(.3 MOLES/LITER)/(.4 LITERS) HAS UNITS OF
'MOLES/LITER SQUARED'.

HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE .3 MOLAR SOLN? .15
UNITS ARE OKAY, BUT YOU ARE USING THE MOLARITY OF ONE SOLUTION,
AND THE VOLUME OF ANOTHER.

```
HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE  .3  MOLAR SOLN? .08
UNITS ARE OKAY, BUT YOU ARE USING THE MOLARITY OF ONE SOLUTION,
AND THE VOLUME OF ANOTHER.

HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE  .3  MOLAR SOLN? .3
UNITS ARE OKAY, BUT YOU ARE USING THE MOLARITY OF ONE SOLUTION,
AND THE VOLUME OF ANOTHER.

HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE  .3  MOLAR SOLN? .12
RIGHT!!  THE EXACT ANSWER IS  .12  MOLES OF NAOH.
WRITE DOWN IN YOUR STUDENT GUIDE WHAT YOU DID --

E.G   ( .3  MOLES NAOH)( 400  ML NAOH SOLN) (1 LITER NAOH SOLN)
      ---------------------------------------------------------
       (LITER NAOH SOLN)                    (1000 ML NAOH SOLN)

HOW MANY TOTAL MOLES ARE THERE ? .02
  REMEMBER THAT  .1  MOLES ARE CONTRIBUTED BY THE
 .2  MOLAR SOLUTION, AND  .12  ARE CONTRIBUTED BY THE
 .3  MOLAR SOLUTION.

HOW MANY TOTAL MOLES ARE THERE ? .22
RIGHT!!  THE EXACT ANSWER IS  .22  MOLES OF NAOH.
WRITE DOWN IN YOUR STUDENT GUIDE WHAT YOU DID --

 .1  MOLES +  .12  MOLES

WHAT IS THE MOLARITY OF THE FINAL SOLUTION (WHICH OCCUPIES
 1000  ML) ? .44
UNITS ARE OKAY, BUT YOU ARE USING MOLES OF ONE SOLUTION
AND VOLUME OF ANOTHER.

WHAT IS THE MOLARITY OF THE FINAL SOLUTION (WHICH OCCUPIES
 1000  ML) ? .00022
( .22  MOLES) / ( 1000  ML) HAS UNITS 'MOLES/ML'

WHAT IS THE MOLARITY OF THE FINAL SOLUTION (WHICH OCCUPIES
 1000  ML) ? .22
RIGHT! THE EXACT ANSWER IS  .22  MOLES NAOH/LITER NAOH SOLN.
WRITE DOWN IN YOUR STUDENT GUIDE WHAT YOU DID --

E.G       ( .22  MOLES NAOH)  (1000 ML NAOH SOLN)
          ---------------------------------------
         ( 1000  ML NAOH SOLN) (1 LITER NAOH SOLN)
CONGRADULATIONS! YOU FINISHED,SO YOU CAN BE CONFIDENT THAT
YOU UNDERSTAND DILUTION.

READY
```

LIST DILUTE Program Listing

```
DILUTE  11:43           24-JUN-75
2 REM    DILUTE  TUTORIAL PROGRAM FOR CHEMICAL DILUTION
4 REM WRITTEN BY R.T.O'NEILL, XAVIER UNIV.,CINCINNATI 45207
6 REM NSF WORKSHOP,IIT,8/1974; DILUTION UNIT OF SOLUTIONS MODULE
7 REM      CHECK LINES 200,210,2060,2120,3060,3120 FOR COMPATIBILITY
8 REM WITH YOUR SYSTEM'S RANDOM NUMBERS AND COMPUTED GOTO'S.
50PRINT"  IN THIS TUTORIAL ON DILUTION, ANSWER THE QUESTIONS WITH"
51PRINT"NUMBERS -- E.G  2.0 AND NOT 6/3 OR 1.33*1.5."
52 PRINT
53PRINT"PRESS THE 'RETURN' OR 'NEW LINE' KEY AFTER TYPING THE NUMBER."
200 RANDOMIZE
210 DEF FNA(L,U)=INT((U-L)*RND(1) +L+.5)
220 DEF FNV = .1*FNA(1,9)
230 DEF FNM = .1*FNA(1,4)
500 LET I = 1
510 REM Q.1
520 LET D = 0
530 LET W = 4*FNA(1,60)
540 LET V = FNV
550 IF W/V>240 THEN 530
560 LET N = .025*W
565 LET M = N/V
566PRINT
567 PRINT"***** QUESTION #1"
568PRINT
570PRINT"YOU WISH TO FIND THE MOLARITY OF NAOH IN A SOLUTION MADE BY"
580PRINT"ADDING TO ";W;" G  OF NAOH (40.0 G /MOLE) ENOUGH WATER"
590PRINT"TO MAKE ";1000*V;" ML OF SOLUTION."
600PRINT
605 LET D = D+1
608 IF D=6 THEN 9000
610PRINT"HOW MANY MOLES OF NAOH ARE THERE ";
620INPUT A1
650GO TO 2000
655PRINT"E.G   (";W;" G NAOH)(1 MOLE NAOH)"
656PRINT TAB(7);"-------------------------"
657PRINT TAB(19);"(40.0 G NAOH)"
660 LET D = 0
680PRINT
685 LET D=D+1
686 IF D=6 THEN 9000
690 PRINT"WHAT IS THE MOLARITY OF THE NAOH IN THE SOLUTION";
700 INPUT A1
710 GO TO 3000
720PRINT"E.G   (";N;" MOLES NAOH)";TAB(28);"(1000 ML NAOH SOLN)"
730PRINT TAB(7);"---------------------------------------"
740PRINT TAB(7);"(";1000*V;" ML NAOH SOLN)";TAB(28);"(1 LITER NAOH SOLN)
"
800 LET I=2
810 REM  Q.2
820 LET D = 0
830 LET V1=FNV
```

```
840 LET M1 = FNM
850 LET M2 =FNM
860 IF M2>=M1 THEN 840
870 LET N=M1*V1
880 LET V=V1
890PRINT
897 PRINT"***** QUESTION #2"
898PRINT
900PRINT"   YOU WISH TO CALCULATE TO WHAT FINAL VOLUME (IN LITERS)"
910PRINT"MUST ";1000*V1;" ML OF A ";M1;" MOLAR SOLUTION OF NAOH BE"
920PRINT"DILUTED IN ORDER TO PREPARE A ";M2;" MOLAR NAOH SOLUTION."
927 LET M = M1
929 LET M1=M2
930 PRINT
935 LET D=D+1
936 IF D=6 THEN 9000
940 PRINT"HOW MANY MOLES OF NAOH ARE THERE ";
950 INPUT A1
960 GO TO 2000
970PRINT"E.G   (";M;" MOLES NAOH)(";1000*V1;" ML NAOH SOLN)";
971PRINT TAB(46)"(1 LITER NAOH SOLN)"
972 PRINT TAB(7);"-------------------------------------------------------
-----"
973PRINT TAB(7);"(1 LITER NAOH SOLN)";TAB(46);"(1000 ML NAOH SOLN)"
980 LET D = 0
982 LET M2=M1
983 LET M1=M
984 LET M=M2
990PRINT
995 LET D=D+1
996 IF D=6 THEN 9000
1000 PRINT"  WHAT IS THE FINAL VOLUME (IN LITERS) TO WHICH THIS ";N
1010 PRINT"MOLES OF NAOH MUST BE DILUTED SO THAT ";M
1011 PRINT"MOLES NAOH / LITER NAOH SOLUTION WILL BE THE "
1012PRINT"FINAL CONCENTRATION";
1020 INPUT A1
1025 LET V=N/M
10$30 LET A9 = V
1040 GOSUB 8000
1050 IF R=0 THEN 1120
1060 PRINT"RIGHT! THE EXACT ANSWER IS ";V;" LITERS OF NAOH SOLUTION."
1070 GOSUB 8200
1080PRINT"E.G   (";N;" MOLES NAOH)";TAB(27);"(1 LITER NAOH SOLN)"
1081PRINT TAB(7);"---------------------------------------"
1082 PRINT TAB(27);"(";M;" MOLES NAOH)"
1090 GO TO 1500
1120 LET A9 = 1000*V
1130 GOSUB 8000
1140 IF R = 0 THEN 1170
1150 PRINT"YOU WERE ASKED FOR LITERS, NOT ML"
1160 GO TO 990
1170 LET A9=M*N
1175 GOSUB 8000
1180 IF R = 0 THEN 1210
1190PRINT"(";M;" MOLES /LITER)(";N;" MOLES) HAS UNITS 'MOLES SQUARED/LIT
ER'"
1200 GO TO 990
```

```
1210 LET A9 = 1/V
1220 GOSUB 8000
1230 IF R= 0 THEN 1260
1240PRINT"(";M;" MOLES/LITER)/(";N;" MOLES) HAS UNITS '1/LITERS'"
1250GO TO 990
1260 GOSUB 8300
1270 GOTO 990
1500 D=0
1510 REM Q.3
1520 LET M1 = FNM
1530 LET M2= FNM
1535 IF M1=M2 THEN 1520
1540 LET V1 = FNV
1550 LET V2 = FNV
1555 IF V1=V2 THEN 1540
1560 LET V3 = V1 + V2 + .1
1567 PRINT
1568PRINT"***** QUESTION #3"
1569 PRINT
1570PRINT"  A ";V1*1000;" ML SAMPLE OF ";M1;" MOLAR NAOH SOLUTION"
1580PRINT"IS MIXED WITH A ";V2*1000;" ML SAMPLE OF ";M2;" MOLAR NAOH"
1590PRINT"SOLUTION. ENOUGH WATER IS THEN ADDED TO GIVE ";V3*1000;"ML"
1600PRINT"OF SOLUTION. CALCULATE THE MOLARITY OF THE FINAL SOLUTION."
1610 LET I = 3
1620 LET N1 = M1*V1
1630 LET N2=M2*V2
1640 LET N3=N1+N2
1660 LET M = M1
1670 LET N = N1
1680 LET V = V1
1682 LET V1=V2
1683 LET M1=M2
1684 LET V2=V3
1690 PRINT
1692 LET D=D+1
1694 IF D=6 THEN 9000
1700PRINT"HOW MANY MOLES NAOH ARE CONTRIBUTED BY THE ";M;" MOLAR SOLN";
1710INPUT A1
1720 GO TO 2000
1730PRINT"E.G   (";M;" MOLES NAOH)(";1000*V;" ML NAOH SOLN)";TAB(44);
1731PRINT"(1 LITER NAOH SOLN)"
1732PRINT TAB(7);"-------------------------------------------------------
----"
1733PRINT TAB(7);"(LITER NAOH SOLN)";TAB(44);"(1000 ML NAOH SOLN)"
1740 IF I = 4 THEN 1800
1745 LET M1=M
1750 LET M = M2
1760 LET N=N2
1762 LET D = 0
1764 LET V2=V1
1766 LET V1=V
1768 LET V=V2
1770 LET V2=V3
1780 LET I = 4
1790 GOTO 1690
1800 LET M2 = M
1805 LET D = 0
```

```
1807 PRINT
1810 PRINT"HOW MANY TOTAL MOLES ARE THERE ";
1820 INPUT A1
1830 LET A9=N3
1840 GOSUB 8000
1850IF R = 1 THEN 1920
1860PRINT"  REMEMBER THAT ";N1;" MOLES ARE CONTRIBUTED BY THE"
1870PRINT M1;" MOLAR SOLUTION, AND ";N2;" ARE CONTRIBUTED BY THE"
1880PRINT M2;" MOLAR SOLUTION."
1890 LET D=D+1
1900 IF D=3 THEN 9000
1910 GOTO 1807
1920 LET N = N1+N2
1925 GOSUB 8400
1927 GOSUB 8200
1930 PRINT N1;" MOLES + ";N2;" MOLES"
1932 LET M= N3/V3
1934 LET V2=V
1936 LET V=V3
1938 LET D=0
1940 PRINT
1943 LET D=D+1
1944 IF D=6 THE
N 9000
1950PRINT"WHAT IS THE MOLARITY OF THE FINAL SOLUTION (WHICH OCCUPIES"
1955PRINT V3*1000;" ML) ";
1960 INPUT A1
1964 LET V=V3
1970 LET I=2
1980 GO TO 3000
1990PRINT"E.G        (";N3;" MOLES NAOH)  (1000 ML NAOH SOLN)"
1991PRINT"           ----------------------------------------"
1992PRINT"          (";V3*1000;" ML NAOH SOLN) (1 LITER NAOH SOLN)"
1993 OPEN "DILUTE.REC[231,10]"AS FILE 1: INPUT #1,M
1994 CLOSE #1
1995 PRINT: OPEN"DILUTE.REC[231,10]" AS FILE 1: PRINT#1,M+1
1996PRINT"CONGRADULATIONS! YOU FINISHED,SO YOU CAN BE CONFIDENT THAT"
1997PRINT"YOU UNDERSTAND DILUTION."
1998 REM LINES 1993-1995 FOR USE CHECK; CAN BE OMITTED
1999 GO TO 9999
2000 LET A9=N
2010REM CHECK ON MOLES
2020 GOSUB 8000
2030 IF R=0 THEN 2070
2040 GOSUB 8400
2050 GOSUB 8200
2060 ON I GOTO 655,970,1730,1730
2070 IF I>1 THEN 2260
2075 LET A9 = 1/N
2080 GOSUB 8000
2090 IF R = 0 THEN 2130
2110 PRINT"(40.0 G /MOLE)/(";W;"G )  HAS UNITS  '1/MOLE' "
2120 ON I GOTO 600,930,1690,1690
2130 LET A9 = W/V
2140 GOSUB 8000
2150 IF R =0 THEN 2180
2160PRINT"YOU SEEM TO BE USING VOLUME. THERE ARE NO 'ML' OR 'LITERS' IN
'MOLES'."
```

```
2170 GOTO 2120
2180 LET A9=.001*W/V
2200 GOSUB 8000
2210 IF R = 0 THEN 2220
2215 GOTO 2160
2220 GOSUB 8300
2230 GO TO 2120
2260 LET A9 = N*1000
2270 GOSUB 8000
2280 IF R = 0 THEN 2320
2290PRINT"(";1000*V;" ML)(";M;" MOLES/LITER) HAS UNITS OF ";
2300PRINT"'ML MOLES/LITER'."
2310 GOTO 2120
2320 LET A9=V/M
2330 GOSUB 8000
2340 IF R = 0 THEN 2380
2350PRINT"(";V;" LITERS/(";M;" MOLES/LITER) HAS UNITS OF"
2360PRINT"'LITERS SQUARED/MOLE'."
2370 GOTO 2120
2380 LET A9 = V*M1
2390 GOSUB 8000
2400 IF R = 0 THEN 2440
2410PRINT"UNITS ARE OKAY, BUT YOU ARE USING THE MOLARITY OF ONE SOLUTION
,"
2420PRINT"AND THE VOLUME OF ANOTHER."
2430 GOTO 2120
2440 LET A9 = M/V
2450 GOSUB 8000
2460 IF R = 0 THEN 2500
2470 PRINT"(";M;" MOLES/LITER)/(";V;" LITERS) HAS UNITS OF "
2480PRINT"'MOLES/LITER SQUARED'."
2490 GOTO 2120
2500 IF I = 2 THEN 2220
2510 LET A9 = V*M2
2520 GOSUB 8000
2530 IF R = 1 THEN 2410
2540 LET A9 = M*V1
2550 GOSUB 8000
2560 IF R = 1 THEN 2410
2570 LET A9 = M*V2
2580 GOSUB 8000
2590 IF R = 1 THEN 2410
2600 GOTO 2220
3000 LET A9 = M
3010 REM CHECK ON MOLARITY
3020 GOSUB 8000
3030 IF R = 0 THEN 3070
3040 GOSUB 8500
3050 GOSUB 8200
3060 ON I GOTO 720,1990
3070 LET A9=.001*M
3080 GOSUB 8000
3090 IF R=0 THEN 3130
3100PRINT"(";N;" MOLES) / (";1000*V;" ML) HAS UNITS 'MOLES/ML'"
3120 ON I GOTO 680,1940
3130 LET A9 = V/N
3140 GOSUB 8000
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3150 IF R = 0 THEN 3180
3160 PRINT"(";V;" LITERS) / (";N;" MOLES) HAS UNITS 'LITERS/MOLE'"
3170 GOTO 3120
3180 IF I = 1 THE



N 3330
3190 LET A9=N1/V
3200 GOSUB 8000
3210 IF R = 0 THEN 3240
3220PRINT"UNITS ARE OKAY, BUT YOU ARE USING MOLES OF ONE SOLUTION"
3221PRINT"AND VOLUME OF ANOTHER."
3230 GOTO 3120
3240 LET A9=N2/V
3250 GOSUB 8000
3260 IF R = 1 THEN 3220
3270 LET A9 = N/V1
3280 GOSUB 8000
3290 IF R = 1 THEN 3220
3300 LET A9=N/V1
3310 GOSUB 8000
3320 IF R=1 THEN 3220
3330 GOSUB 8300
3440 GOTO 3120
8000 LET R = 0
8010 REM CHECK IF ANS. 5% OF CORRECT
8030 IF A1 >1.05*A9 THEN 8060
8040 IF A1 < .95*A9 THEN 8060
8050 LET R=1
8060 RETURN
8200PRINT"WRITE DOWN IN YOUR STUDENT GUIDE WHAT YOU DID --"
8210 REM AFTER Q. ANS. CORRECTLY
8220PRINT
8230 RETURN
8300 PRINT"  THIS ANSWER IS NOT WITHIN 5% OF THE CORRECT ANSWER, BUT"
8310 REM FOR INCORRECT ANSWER WITH NO DIAGNOSED ERROR.
8320 PRINT"YOU MAY BE DOING THE PROBLEM CORRECTLY, AND MERELY MAKING"
8340 PRINT"AN ARITHMETIC ERROR. CHECK YOUR CALCULATION WITH PENCIL"
8350PRINT"AND PAPER."
8360 RETURN
8400PRINT "RIGHT!!  THE EXACT ANSWER IS ";N;" MOLES OF NAOH."
8410 REM FOR A MOLES CALCULATION
8420 RETURN
8500 PRINT"RIGHT! THE EXACT ANSWER IS ";M;" MOLES NAOH/LITER NAOH SOLN."
8510 REM FOR A MOLARITY CALCULATION
8520 RETURN
9000PRINT"   YOU DON'T SEEM TO UNDERSTAND THE UNDERLYING CONCEPTS."
9010PRINT"PERHAPS YOU HAD BETTER RESTUDY THE STUDENT'S GUIDE BEFORE"
9020PRINT"TRYING THIS PROGRAM AGAIN."
9999 END

READY
```

Unit Test on Dilution Problems

TEST 1

1. 19.2 ML OF A 0.505 M SOLUTION OF KNO_3 IS DILUTED TO 174 ML. WHAT IS THE MOLARITY OF THE NEW SOLUTION?

2. A 70.7 ML SAMPLE OF CONCENTRATED $CuSO_4 \cdot 5H_2O$ SOLUTION IS DILUTED UNTIL THE FINAL VOLUME IS 99.0 ML. THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.2 G/ML AND IT IS 70.2 % PURE $CuSO_4 \cdot 5H_2O$. WHAT IS THE MOLARITY OF THE FINAL SOLUTION ?

3. HOW MANY ML OF 14.1% KNO_3 SOLUTION SHOULD BE USED TO PREPARE 104 ML OF 0.331 M KNO_3 ? THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.114 G/ML .

4. HOW MANY ML OF 2.980 M $Al_2(SO_4)_3$ IS REQUIRED IN THE PREPARATION OF 24.0 ML OF 0.193 M $Al_2(SO_4)_3$?

TEST 1

1. 5.57E-02

2. 2.35E+00

3. 2.21E+01

4. 1.55E+00

Unit Test on Dilution Problems

TEST 2

1. HOW MANY ML OF 35.1% KIO_3 SOLUTION SHOULD BE USED TO PREPARE 75 ML OF 1.142 M KIO_3 ? THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.135 G/ML .

2. 41.9 ML OF A 2.250 M SOLUTION OF $Ni(NO_3)_2$ IS DILUTED TO 331 ML. WHAT IS THE MOLARITY OF THE NEW SOLUTION?

3. HOW MANY ML OF 3.433 M $Al_2(SO_4)_3$ IS REQUIRED IN THE PREPARATION OF 62.5 ML OF 0.453 M $Al_2(SO_4)_3$?

4. A 59.4 ML SAMPLE OF CONCENTRATED $NaClO_3$ SOLUTION IS DILUTED UNTIL THE FINAL VOLUME IS 121.7 ML. THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.1 G/ML AND IT IS 19.4 % PURE $NaClO_3$. WHAT IS THE MOLARITY OF THE FINAL SOLUTION ?

TEST 2

1. 4.67E+01

2. 2.85E-01

3. 8.25E+00

4. 9.96E-01

Unit Test on Dilution Problems

TEST 3

1. HOW MANY ML OF 55.3% $Al_2(SO_4)_3$ SOLUTION SHOULD BE USED TO PREPARE 102 ML OF 0.789 M $Al_2(SO_4)_3$? THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.155 G/ML .

2. HOW MANY ML OF 3.480 M $K_2Cr_2O_7$ IS REQUIRED IN THE PREPARATION OF 62.9 ML OF 0.918 M $K_2Cr_2O_7$?

3. 23.1 ML OF A 4.370 M SOLUTION OF $NaClO_3$ IS DILUTED TO 531 ML. WHAT IS THE MOLARITY OF THE NEW SOLUTION?

4. A 73.6 ML SAMPLE OF CONCENTRATED Na_2CO_3 SOLUTION IS DILUTED UNTIL THE FINAL VOLUME IS 103.9 ML. THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.1 G/ML AND IT IS 9.5 % PURE Na_2CO_3. WHAT IS THE MOLARITY OF THE FINAL SOLUTION ?

TEST 3

1. 4.30E+01

2. 1.66E+01

3. 1.65E-01

4. 7.04E-01

Unit Test on Dilution Problems

TEST 4

1. HOW MANY ML OF 91.8% $K_2Cr_2O_7$ SOLUTION SHOULD BE USED TO PREPARE 143 ML OF 1.824 M $K_2Cr_2O_7$? THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.192 G/ML .

2. 21.8 ML OF A 3.205 M SOLUTION OF KNO_3 IS DILUTED TO 314 ML. WHAT IS THE MOLARITY OF THE NEW SOLUTION?

3. HOW MANY ML OF 1.840 M KBr IS REQUIRED IN THE PREPARATION OF 13.1 ML OF 0.746 M KBr ?

4. A 85.6 ML SAMPLE OF CONCENTRATED $NaClO_3$ SOLUTION IS DILUTED UNTIL THE FINAL VOLUME IS 188.7 ML. THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.2 G/ML AND IT IS 97.4 % PURE $NaClO_3$. WHAT IS THE MOLARITY OF THE FINAL SOLUTION ?

TEST 4

1. 7.01E+01

2. 2.23E-01

3. 5.31E+00

4. 4.97E+00

Unit Test on Dilution Problems

TEST 5

1. A 64.2 ML SAMPLE OF CONCENTRATED $Al_2(SO_4)_3$ SOLUTION IS DILUTED UNTIL THE FINAL VOLUME IS 141.4 ML. THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.1 G/ML AND IT IS 5.3 % PURE $Al_2(SO_4)_3$. WHAT IS THE MOLARITY OF THE FINAL SOLUTION ?

2. HOW MANY ML OF 43.3% $Ni(NO_3)_2$ SOLUTION SHOULD BE USED TO PREPARE 95 ML OF 0.694 M $Ni(NO_3)_2$? THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.143 G/ML .

3. HOW MANY ML OF 1.760 M $Al_2(SO_4)_3$ IS REQUIRED IN THE PREPARATION OF 11.8 ML OF 0.313 M $Al_2(SO_4)_3$?

4. 25.8 ML OF A 2.100 M SOLUTION OF $BaCl_2$ IS DILUTED TO 554 ML. WHAT IS THE MOLARITY OF THE NEW SOLUTION?

TEST 5

1. 7.77E-02

2. 2.45E+01

3. 2.10E+00

4. 1.01E-01

TEST 6

1. A 5.7 ML SAMPLE OF CONCENTRATED $(NH_4)_3PO_4$ SOLUTION IS DILUTED UNTIL THE FINAL VOLUME IS 91.4 ML. THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.1 G/ML AND IT IS 32.0 % PURE $(NH_4)_3PO_4$. WHAT IS THE MOLARITY OF THE FINAL SOLUTION ?

2. HOW MANY ML OF 16.5% $AgNO_3$ SOLUTION SHOULD BE USED TO PREPARE 98 ML OF 0.599 M $AgNO_3$? THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.116 G/ML .

3. HOW MANY ML OF 4.010 M $MnCl_2$ IS REQUIRED IN THE PREPARATION OF 68.4 ML OF 0.544 M $MnCl_2$?

4. 40.4 ML OF A 1.500 M SOLUTION OF $BaCl_2$ IS DILUTED TO 286 ML. WHAT IS THE MOLARITY OF THE NEW SOLUTION?

TEST 6

1. 1.43E-01

2. 5.43E+01

3. 9.28E+00

4. 2.20E-01

Unit Test On Dilution Problems

TEST 7

1. HOW MANY ML OF 63.9% $KMnO_4$ SOLUTION SHOULD BE USED TO PREPARE 108 ML OF 0.283 M $KMnO_4$? THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.164 G/ML .

2. 30.0 ML OF A 5.000 M SOLUTION OF $(NH_4)_3PO_4$ IS DILUTED TO 550 ML. WHAT IS THE MOLARITY OF THE NEW SOLUTION?

3. A 87.7 ML SAMPLE OF CONCENTRATED $KMnO_4$ SOLUTION IS DILUTED UNTIL THE FINAL VOLUME IS 163.4 ML. THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.2 G/ML AND IT IS 71.9 % PURE $KMnO_4$. WHAT IS THE MOLARITY OF THE FINAL SOLUTION ?

4. HOW MANY ML OF 2.010 M $Al_2(SO_4)_3$ IS REQUIRED IN THE PREPARATION OF 14.3 ML OF 0.733 M $Al_2(SO_4)_3$?

TEST 7

1. 6.50E+00

2. 3.27E-01

3. 2.86E+00

4. 5.21E+00

Unit Test on Dilution Problems

TEST 8

1. A 50.4 ML SAMPLE OF CONCENTRATED $Al_2(SO_4)_3$ SOLUTION IS DILUTED UNTIL THE FINAL VOLUME IS 91.4 ML. THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.2 G/ML AND IT IS 95.3 % PURE $Al_2(SO_4)_3$. WHAT IS THE MOLARITY OF THE FINAL SOLUTION ?

2. 21.5 ML OF A 4.440 M SOLUTION OF Na_3PO_4 IS DILUTED TO 75 ML. WHAT IS THE MOLARITY OF THE NEW SOLUTION?

3. HOW MANY ML OF 3.240 M KBr IS REQUIRED IN THE PREPARATION OF 27.2 ML OF 0.286 M KBr ?

4. HOW MANY ML OF 44.4% $MnCl_2$ SOLUTION SHOULD BE USED TO PREPARE 184 ML OF 2.114 M $MnCl_2$? THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.144 G/ML .

TEST 8

1. 1.84E+00

2. 1.27E+00

3. 2.40E+00

4. 9.63E+01

Unit Test on Dilution Problems

TEST 9

1. 48.2 ML OF A 2.860 M SOLUTION OF $BaCl_2$ IS DILUTED TO 934 ML. WHAT IS THE MOLARITY OF THE NEW SOLUTION?

2. A 30.7 ML SAMPLE OF CONCENTRATED $BaCl_2$ SOLUTION IS DILUTED UNTIL THE FINAL VOLUME IS 103.7 ML. THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.2 G/ML AND IT IS 59.2 % PURE $BaCl_2$. WHAT IS THE MOLARITY OF THE FINAL SOLUTION ?

3. HOW MANY ML OF 45.5% Na_2CO_3 SOLUTION SHOULD BE USED TO PREPARE 160 ML OF 1.501 M Na_2CO_3 ? THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.145 G/ML .

4. HOW MANY ML OF 1.610 M $Cd(NO_3)_2$ IS REQUIRED IN THE PREPARATION OF 10.3 ML OF 0.156 M $Cd(NO_3)_2$?

TEST 9

1. 1.65E-01

2. 9.75E-01

3. 4.87E+01

4. 9.98E-01

Unit Test on Dilution Problems

TEST 10

1. HOW MANY ML OF 81.7% $FeCl_3$ SOLUTION SHOULD BE USED TO PREPARE 112 ML OF 3.601 M $FeCl_3$? THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.182 G/ML .

2. HOW MANY ML OF 3.470 M $CrCl_3$ IS REQUIRED IN THE PREPARATION OF 62.4 ML OF 0.449 M $CrCl_3$?

3. A 9.1 ML SAMPLE OF CONCENTRATED $Ni(NO_3)_2$ SOLUTION IS DILUTED UNTIL THE FINAL VOLUME IS 76.3 ML. THE DENSITY OF THE CONCENTRATED SOLUTION IS 1.2 G/ML AND IT IS 59.0 % PURE $Ni(NO_3)_2$. WHAT IS THE MOLARITY OF THE FINAL SOLUTION ?

4. 32.7 ML OF A 4.730 M SOLUTION OF KBr IS DILUTED TO 539 ML. WHAT IS THE MOLARITY OF THE NEW SOLUTION?

TEST 10

1. 6.78E+01

2. 8.07E+00

3. 4.46E-01

4. 2.87E-01